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Stock assessment and recommended harvest For Pacific Sardine in 2002

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ABSTRACT

The Canadian commercial fishery for Pacific sardine ended in the late 1940s as a result of declining abundance off California. After an absence of almost 50 years, sardine reappeared in British Columbia in the early 1990s and an experimental fishery commenced in 1995. As interest in re-establishing a commercial fishery has grown, small increments in the experimental fishery have occurred to present with 10 licensees (7 seine, 2 trap, 1 gillnet) harvesting a quota of 1600 tons in 2001. Ongoing summer trawl surveys provide an index of relative abundance in the offshore waters and indications for 2001 are that sardines were distributed further south and were less abundant than in 1997 and 1999 surveys. These results are consistent with the U.S. assessment which indicates a slight decline in sardine abundance in 2001. The Canadian stock assessment is based on the U.S. abundance forecast and assumes that on average about 10% of the stock migrates into BC waters based on historical catch rates and biomass estimates from the trawl survey. Given developing expertise in catching and handling sardines in the Canadian industry it was recommended that the U.S. harvest rate based on temperature conditions near the spawning grounds be adopted for the B.C. fishery. Indications from the U.S. assessment for 2002 are that sardine biomass are declining slightly, but at the recommended harvest rate of 15%, a potential surplus of 15,864 tonnes is forecast for 2002 in Canadian waters. It should be noted that this represents a harvest ceiling and if July and August 2002 temperatures off the lower west coast of Vancouver Island are near, or below, the 12C migration threshold, the biomass of sardines migrating to BC could be lower than forecast.

RÉSUMÉ

La pêche commerciale canadienne de la sardine du Pacifique s'est terminée à la fin des années 1940 parce que l'espèce était moins abondante au large de la Californie. Absente pendant près de 50 ans, la sardine est réapparue en Colombie-Britannique au début des années 1990, et une pêche expérimentale a commencé en 1995. Devant l'intérêt grandissant pour le rétablissement de la pêche commerciale, on a étendu très progressivement la pêche expérimentale, avec 10 détenteurs de permis (7 bateaux de pêche à la senne, 2 au filet de fond et 1 au filet maillant) récoltant un quota de 1 600 tonnes en 2001. Des relevés d'été continus au chalut fournissent un indice de l'abondance relative de l'espèce en zone hauturière, et il semble qu'en 2001, les sardines se trouvaient plus au sud et étaient moins abondantes que lors des relevés de 1997 et de 1999. Ces résultats sont cohérents avec l'évaluation des É.-U. qui révèle une légère diminution de l'abondance de sardine en 2001.

L'évaluation canadienne du stock repose sur la prévision de l'abondance faite par les É.-U. et suppose qu'en moyenne, environ 10 % du stock migre vers les eaux de la C.-B. d'après les taux de capture historiques et les estimations de la biomasse découlant du relevé au chalut. L'industrie canadienne devenant de plus en plus experte de la capture et de la manutention des sardines, il a été recommandé d'adopter, pour la pêche de la C.-B., le taux de récolte des É.-U. basé sur les conditions de température près des frayères. Selon l'évaluation des É.-U. pour 2002, la biomasse de sardine fléchit légèrement, mais au taux de récolte recommandé de 15 %, on prévoit un excédent potentiel de 15 864 tonnes dans les eaux canadiennes. Cette récolte constitue un plafond et, si les températures en juillet et en août 2002 au large de la côte ouest inférieure de l'île de Vancouver sont près ou en dessous du seuil de migration de 12 °C, la biomasse des sardines qui migrent vers la C.-B. pourrait être inférieure à la prévision.

INTRODUCTION

The Pacific sardine (*Sardinops sagax*) has been primarily a transient visitor to Canadian waters, migrating northward from California in the spring to the rich feeding grounds off Vancouver Island and returning south in the fall. It was fished extensively in the Pacific northwest during the first half of the 20th century disappearing entirely from this area by the late 1940s. After an absence of almost 50 years, sardines reappeared in Canadian waters in 1992 (Hargreaves et al. 1994, McFarlane and Beamish 2001). As a result, there has been some debate about the prevalence of sardine spawning in Canadian waters and the possible existence of a northern sardine stock. Hart (1973) reports that sardines with loose eggs have been found in Canadian waters but no spawning was known to occur here. Ware (1999) cites an unpublished report that provides evidence for sardine spawning off the Canadian coast in the 1920s. Recently, ripe females were collected on the west coast of Vancouver Island in July, 1997 and subsequently age 0 juveniles the following March and April, suggesting successful spawning in the area (McFarlane and Beamish 2001). Bentley et al. (1996) also report on recent sardine egg production off the coast of Oregon. Thus, it appears that some egg production has occurred in northern waters and resulted in viable sardines, but in all likelihood these spawners are part of the California population. There is also anecdotal evidence that some sardines over-wintered in inlets on the west coast of Vancouver Island rather than migrating south in the fall (Hart 1937). This was confirmed by recent observations of sardines over-wintering in the inlets of the west coast of Vancouver Island and the Central Coast of British Columbia during 1997 and 1998. However, it appears these fish represent schools of sardines being trapped in warm water cells since subsequent die-offs of sardines occurred in some of these areas in the late winter. At the same time, quantities of healthy sardine were observed offshore in early 1998 where water temperatures were warmer (McFarlane and MacDougall 2001). In summary, there is no apparent evidence of distinct sardine stocks in Canadian waters and available data suggest that the northward migration is constrained by the 12C isotherm (Ware 2001). Consequently, as the California sardine population has rebuilt over the past few decades the abundance of fish migrating into BC waters has increased, particularly during the anomalously warm conditions associated with the 1997/98 ENSO event, as has the interest in harvesting them. This report briefly describes the history of the Canadian experimental sardine fishery since 1995, observations of sardine distribution and relative abundance in 2001, and recommendations for an allowable harvest in 2002 based on the protocol proposed by Ware (1999).

THE EXPERIMENTAL FISHERY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) identified the Pacific sardine as a vulnerable species or one of special concern in 1987 (Schweigert 1988). As a result, no directed commercial harvest of this species has been permitted to date despite the remarkable recovery of the California population as a whole. COSEWIC is currently reviewing the status of sardine.

In the interim, an experimental fishery has been conducted to investigate the availability of sardines along the BC coast, marketability of the product, viable fishing gears, and stability and economic viability of the market for sardines. According to Ware (1999), sardines were first observed in abundance in Nootka, Kyuquot, and Quatsino Sounds in 1995 and Mr. R. Leo obtained an experimental license, apparently making a 100 ton set with a herring purse seine in late November, thus becoming the first BC fishermen to commercially capture sardine since the 1940s. Mr. Leo subsequently obtained an experimental license in 1996 for 350 tons and was able to harvest 163 tons (148 tonnes), but as noted in the table below much of this product was not sold. In 1997, under the federal/provincial memorandum of understanding (MOU) on fisheries and seafood diversification, a pilot experimental fishery was implemented with seven participants licensed to harvest 80 tons (73 tonnes) per license. Experimental efforts have increased each successive year to a high of 200 tons (181 tonnes) per license in 2000. In 2001, seven experimental seine licenses were again issued for 200 tons with an additional two licenses of 90 tons (82 tonnes) each for two trap operations and one license for 10 tons (9 tonnes) for a gillnet fisherman to investigate the efficacy of alternative gear types. Due to the timing of these latter permits only one of the traps operated in 2001.

Table 1. Historical catch (tons) of Pacific sardine by Statistical Area in the experimental fishery since 1995 based on validated landings.*

	Area								Total
	8	10	12	23	24	25	26	27	(tons)
1995						25			25
1996							88		88
1997			30	4					34
1998		179	332		120	104	10		745
1999	9	388	381	82		10	270	110	1250
2000	61		88	229		847	160	333	1718

*Figures do not include by-catch of sardines in trawl fisheries.

It is evident from Table 1 that most of the catch to date has come from the upper west coast of Vancouver Island and the lower Central Coast/Queen Charlotte Sound area. Catch locations for the 2000 fishery are shown in Figure 1. Based on the results for the 2000 fishery there has been little seasonal difference in catches with similar catches occurring in August, September and November and a smaller catch in October (Table 2). However, it isn't clear how much of this pattern is due to availability of fish inshore and access to offload facilities and how much to actual distribution of sardines. Seasonally, less of the catch occurred in the north later in the season presumably as a result of fish beginning their southward migration.

Table 2. Total 2000 Pacific sardine catch (tons) by month and Statistical Area.

Month	*Statistical Area*						
	8	**12**	**23**	**25**	**26**	**27**	**Total for Month**
Aug	61.08	42.25	94.89		160.01	137.56	495.81
Sept		45.45	134.48	207.54		195.71	583.18
Oct				183.06			183.06
Nov				456.74			456.74
Total for Area	**61.08**	**87.71**	**229.38**	**847.34**	**160.01**	**333.27**	**1718.79**

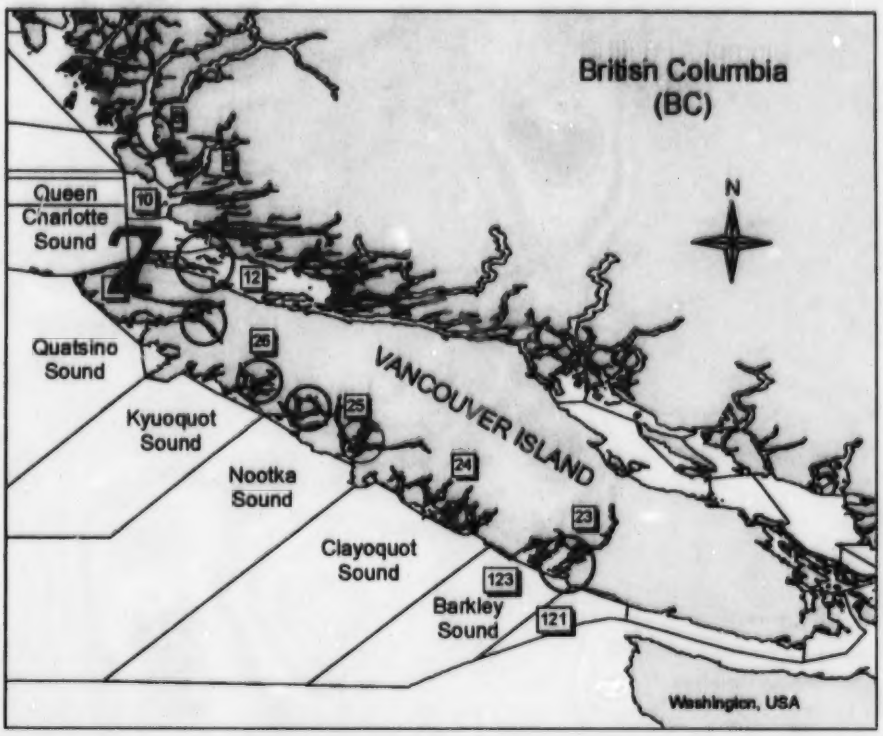

Figure 1. Sardine catch locations for the 2000 fishery. Statistical Areas denoted in the boxes.

The fishery in 2001 has been quite successful but only preliminary catch figures are available at this time and are not reported here. Preliminary estimates of the total by-catch during the 2001 fishery based on the weight of other species taken in the sardine fishery suggest that by-catch amounted to less than 1% of the total weight landed. In terms of numbers of individuals, mackerel accounted for more than half the by-catch (52.9%, Figure 2). The remainder of the by-catch consisted of dogfish (27.3%), various salmonids (8.3%), shrimp (5.6%), and hake (4.3%).

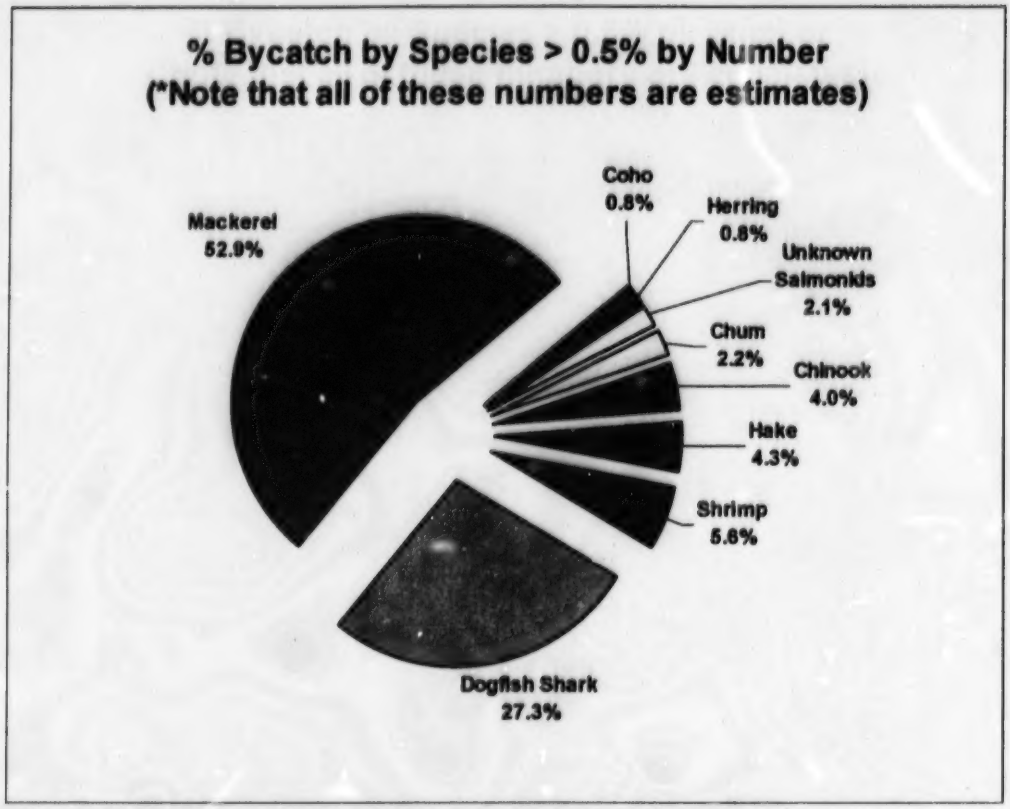

Figure 2. Estimated by-catch in numbers from the 2001 sardine fishery.

TRAWL SURVEY SUMMARY

Surveys employing mid-water trawls near the surface have been conducted on the west coast of Vancouver Island from 1992 to present to examine the distribution and relative abundance of sardines (McFarlane and MacDougall 2001). The July cruises have generally been most indicative of the relative sardine biomass in Canadian offshore waters. Biomass estimates were calculated for the July, 2001 cruise, according to the method described in McFarlane and Beamish (2001). The west coast of Vancouver Island was partitioned into 6 major "regions", and the total surface volume to the maximum depth of the net (30m) was determined for each to allow biomass estimates to be calculated regionally and coastwide (Figure 3). The water volume swept during each tow was determined by multiplying the area of the midwater trawl net used during the fishing operations, by the distance travelled. Minimum and maximum biomass estimates were determined based on the 95 percent confidence interval for the calculated average swept volume within each stratum for the 2001 survey (Table 3). McFarlane and Beamish (2001) report sardine biomass estimates for 1997 and 1999 of 88,843 and 79,398 tonnes from similar

surveys. Both of these earlier surveys found the majority of the sardines in the southern regions 4-6 similar to the 2001 survey, although they also reported sardines in the northern portion of the survey area (regions 1-3). This suggests that overall sardine biomass in the offshore Canadian waters in 2001 was less than in earlier years. However, there have been anecdotal reports of large quantities of sardines in inshore waters in 2001, particularly the inlets along the west coast of Vancouver Island, that would not have been detected by the trawl survey and so would not be included in this estimate. While it is not possible to provide an accurate estimate of the biomass of sardines in inshore waters relative to that observed in the offshore, and hence an assessment of the total sardine biomass in BC, the trawl survey does provides a minimal estimate of the probable sardine biomass in Canadian waters.

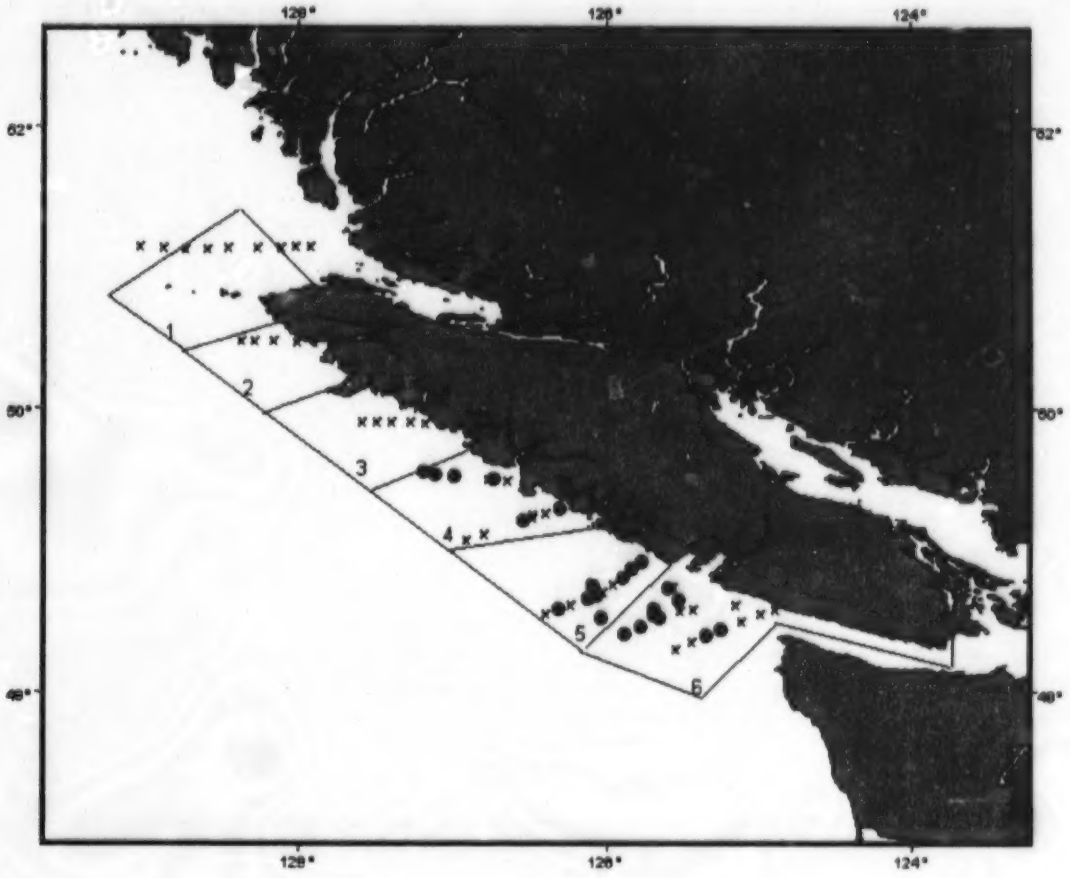

Figure 3. The west coast of Vancouver Island, divided into six regions and showing sets used to determine the 2001 biomass estimate for sardine. Sets are from the July 24 – August 21, 2001 cruise. X's represent sets made at depths of 45 m or shallower in which sardines were not captured, dots represent sets in which sardines were captured.

Table 3. Biomass estimates by region, and overall biomass estimates for the west coast of Vancouver Island, calculated from data collected during the offshore trawl surveys from 1997-2001.

Year	Stratum	Total Volume (km^3)	Ave Swept Vol (km^3)	Swept Volume 95% CI	Average No. per Stratum	Total No. Fish	*Biomass (mt): +/- C.I. Min	Ave	Max
1997	1	91.0	0.0039	0.0007	57	1316578	185	217	264
	2	66.6	0.0042	0.0009	3509	55589704	7499	9172	11838
	3	119.7	0.0031	0.0016	645	24662768	2673	4069	8522
	4	83.9	0.0032	0.0012	12696	332440542	39454	54853	89964
	5	71.8	0.0028	0.0006	1222	31372655	4234	5176	6658
	6	127.7	0.0021	0.0004	1521	93061220	12901	15355	18961
	All						66947	88843	136208
1999	2	66.6	0.0019	0.0002	1180	40875249	6146	6744	7472
	3	119.7	0.0020	0.0001	430	26334474	4127	4345	4588
	4	83.9	0.0019	0.0002	559	25209905	3774	4159	4632
	5	71.8	0.0017	0.0006	1307	52665988	6487	8690	13157
	6	127.7	0.0020	0.0005	5262	330056295	44122	55459	71123
	All						64656	79398	100972
2001	4	83.9	0.0017	0.0005	4	98298	13	16	22
	5	71.8	0.0017	0.0002	4	149410	22	25	29
	6	127.7	0.0017	0.0005	3616	265598220	33804	43824	62285
	All						33839	43845	62336

*Weight conversion of 0.165kg/fish assumed.

STOCK ASSESSMENT AND YIELD RECOMMENDATION

A procedure for determining the probable biomass of Pacific sardines in Canada and a harvestable surplus based on the U.S. stock assessment was proposed by Ware (1999) and accepted by the PSARC Pelagics Subcommittee. We present the results of this approach below for the 2002 fishery. The U.S. stock assessment forms the basis of this approach and is based on an age-structured model which includes two areas (Catch-at-age analysis for sardine – two area model [CANSAR]) (Hill et al. 1999). It is a forward-projecting, age-structured analysis that uses both fishery-dependent and fishery-independent data to obtain annual estimates of sardine abundance. In 1998, CANSAR was modified into a Two-Area-Migration model, which accounts in part for the fraction of the available biomass outside the range of the California based fishery, i.e. for the northward expansion of the population into the Pacific northwest.

The U.S. stock assessment for 2002 estimated a total coastwide biomass of 1.06 million tonnes of sardines (on July 1, 2001), with 596 thousand tons available to the Baja California and Mexican fisheries (Area 1), and about 462 thousand tons northward (and offshore) of California

(Conser et al. 2001). This represents a slight decline from the estimated stock of 1.16 million tonnes in 2001.

The U.S. formula for estimating the recommended sardine harvest is:

$$H = (\text{Total Biomass}_{2001} - \text{Cutoff}) \times \text{Fraction} \times \text{Distribution}$$

where

H = total U.S. harvest (California, Oregon, Washington);
Biomass = total biomass of age 1 and older fish at the beginning of season;
Cutoff = lowest biomass where harvest is allowed (currently 150,000 tonnes);
Fraction = MSY control rule for proportion of stock to be harvested;
Distribution = fraction of stock biomass in U.S. Waters (87% in 2001).

Fraction is a proxy for F_{msy}, which is the fishing mortality rate to achieve MSY and is the environmental-based percentage of the biomass above the Cutoff that can be harvested by the fishery. Fraction depends on ocean temperatures because F_{msy} and sardine productivity are both higher at warmer water temperatures:

$$\text{Fraction or } F_{msy} = 0.249\ T^2 - 8.19\ T + 67.46,$$

where T is the average sea surface temperature at Scripps Pier, California during the preceding three seasons (Conser et al 2001) but F_{msy} is constrained to range between 5 and 15%. Based on the current ocean conditions (T_{2001}= 17.24C) the exploitation fraction for 2002 will remain at 15%. Accordingly, the 2002 harvest guideline will be 118,442 mt which is slightly less than the 134,737 mt estimated for 2001.

Pre-season B.C. Biomass Estimate

Following Ware (1999), a preseason estimate of the biomass of sardine that will potentially migrate to B.C. can be obtained from the following simple relationship:

$$\text{B.C. biomass (tonnes)} = \text{Total Coastwide Biomass (tonnes)} \times \text{Migration rate} \qquad (1)$$

Migration Rate. Historically, the B.C. fishery took about 10% of the combined U.S. and Canadian catch. Assuming the Canadian and U.S. fisheries harvested the available supply of sardines at about the same rate, then about 10% of the sardine population migrated to B.C. in the summer, on average (Ware 1999). A more recent estimate of the migration rate into B.C. waters can be provided by the trawl survey biomass estimates (Table 4). The trawl surveys conducted off the west coast of Vancouver Island sample sardines in offshore waters and do not include the inlets and inshore areas known to contain significant quantities of sardine. Consequently, the upper 95% confidence limit of the biomass estimate from the trawl surveys was assumed to provide a reasonable approximation to the total biomass of sardines in Canadian waters. The fraction that the trawl survey biomass comprises of the estimated total biomass for the population from the US assessment should approximate the migration rate into B.C. For the three trawl

surveys the apparent migration rate ranged from a low of 6% in 2001 to 17% in 1997. The mean for the three surveys was 10.6%, which is co-incidentally identical to the rate determined by Ware (1999) from historical fishery catches. Consequently, for the 2002 assessment, for simplicity we have assumed a migration rate of 10% into Canadian waters. At the present stock level and under favorable conditions, this suggests that about 106 thousand tonnes of sardines could potentially migrate to Canadian waters next summer.

Table 4. Estimates of the migration rate of sardines into British Columbia from 1997-2001 based on the trawl survey biomass estimates.

	US Assessment	Trawl – U.C.I	Migration Rate
1997	799611	136208	0.170
1999	1128472	100972	0.089
2001	1057599	62336	0.059
Mean			0.106

Harvest Rate. The U.S. harvest rate is currently set at the high end of their range at 15% and has a Cutoff biomass of 150 thousand tonnes. Ware (1999) recommended that to be precautionary and because of variability in the migration rate and uncertainty about by-catch, Canada should harvest the sardine stock at a rate which does not exceed 10% of the estimated pre-season biomass of sardines in Canadian waters. However, because the information collected to date on by-catch indicates that it is insignificant and since B.C. fishermen have developed considerable expertise in catching sardine, we recommend that Canada adopt the U.S. harvest rate based on the temperature function. Accordingly, the recommended harvest formula for sardine is:

B.C. Quota = U.S. Biomass x B.C. Migration rate x Harvest Rate

= 1,057,599 x 0.10 x 0.15 = 15,864 tonnes.

The maximum potential harvest based on this approach for 2002 would therefore be 15,864 tonnes and does not represent any risk to the stock amounting to less than 2% of the total forecast stock biomass. It should also be noted that this represents a harvest ceiling and if July and August 2002 temperatures off the lower west coast of Vancouver Island are near, or below, the 12C migration threshold, the biomass of sardines migrating to BC could be much lower than forecast.

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